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Monterey, California

Thermoacoustic Pin Stacks

by

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This technical report describes progress building and testing a "pin stack" during the period 01 June 1995 through 31 May 1996. The pin stack produced 18% higher acoustic pressures, reached onset at a 40% lower mean pressure, and was about 25% more efficient than a conventional rolled stack in a thermoacoustic prime mover. A publications, presentations, and honors report is also included.

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ANNUAL SUMMARY REPORT

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THERMOACOUSTIC PIN STACKS

01 June 1995 - 31 May 1996

by

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ABSTRACT

This annual summary report describes progress building and testing a "pin stack" during the period 01 June 1995 through 31 May 1996. The pin stack produced 18% higher acoustic pressures, reached onset at a 40% lower mean pressure, and was about 25% more efficient than a conventional rolled stack in a thermoacoustic prime mover. A publications, patents, presentations, and honors report is also included.

Description of Project:

The primary objective of this research is to construct and test a "pin stack." This stack geometry is predicted to substantially improve the efficiency of thermoacoustically based refrigerators, heat pumps and prime movers (Swift and Keolian, J. Acoust. Soc. Am. 94 (2), Pt. 1, 941-943, 1993).

Approaches Taken:

A comparison of the pin stack geometry with the conventional rolled geometry has been made in a modular prime mover test rig which uses low pressure neon gas held between room and liquid nitrogen temperatures. The pin stack was constructed by hand sewing a 75 micron constantan wire back and forth about 2300 times between the hot and cold heat exchangers. The wire forms a hexagonal lattice with wires along the acoustic axis spaced 750 microns apart with a 3.2% error rate. A small acoustic driver was added to the rig to allow us to measure the quality factor Q below onset as a function of gas pressure.

Accomplishments Completed:

The pin stack worked pretty much as predicted by theory. In air at room temperature, the Q of the prime mover increased by 18% for the pin stack over the comparison rolled stack, indicating that the pin stack significantly decreases acoustic losses. With neon and the temperature gradient applied, the onset occurs at a mean pressure which is 40% lower for the pin stack compared to the rolled stack. The sound produced is generally 18% louder for the pin stack, and the efficiency of the pin stack is about 25% better than the rolled stack, although this last result has the most uncertainty due to the difficulties of reliably measuring heat flows.

Tom Hofler and his student have similar results for their mesh stacks, and we have all been careful to use similar techniques so that an accurate comparison of these new stack geometries can be made.

Students Associated with Grant:

LT Rodney Gibson, USN, has conducted his M.S. thesis work on this project.

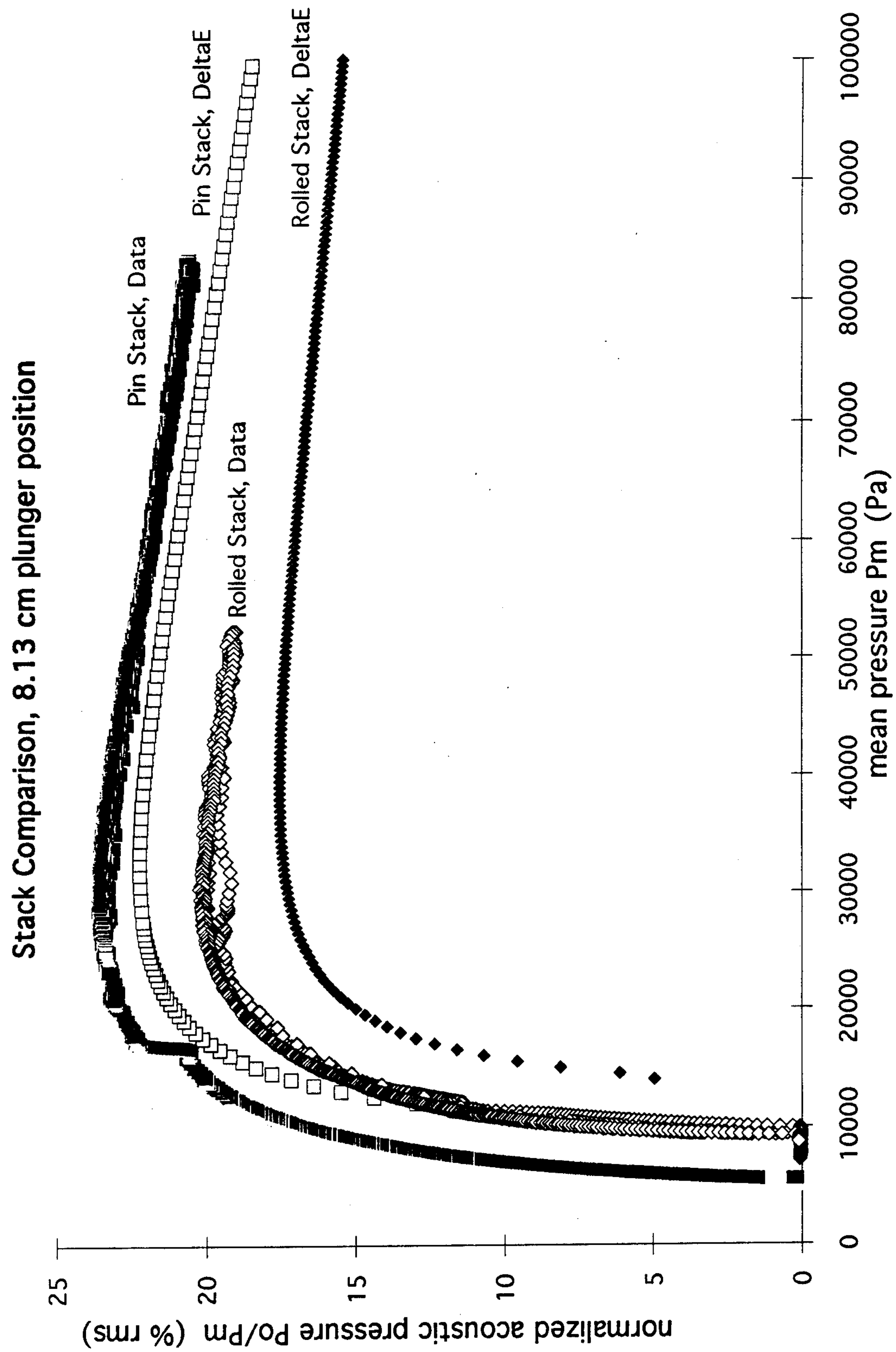
Additional information:

One of the primary purposes of this work is to validate the Los Alamos DeltaE code. A comparison of pin stack and rolled stack data is shown along with DeltaE calculations in the first figure. Except for a slight difference in the spacing of the plates of the heat exchangers, the geometries for the two stack experiments are nearly identical. Plotted is the rms acoustic pressure divided by the mean pressure vs. the mean pressure. The glitch in the pin stack data was caused by letting the liquid nitrogen level in the dewar get too low, as the mean neon pressure was going up. We caught this, added nitrogen, and the sound level jumped up. Due to a problem, we were not able to bring the pressure back down through this region.

The simulations were made with parameters appropriate for 27 kPa, where the design of the pin stack was optimized. Because of the heat load, the cold exchanger was seen to warm up to 106 K in previous experiments with the rolled stack from the ideal liquid nitrogen temperature, and for simplicity this warmer temperature, and 310 K for the hot exchanger, was used in the DeltaE simulations for all mean pressures. However, in the experiment the heat load on the exchangers largely goes away at onset and the temperature gradient is higher than in the simulations. Thus, the experimental results have a lower onset pressure than our DeltaE predictions. More careful use of DeltaE should fix this. However, the code does not appear to be grossly wrong, and this should come as a comfort to Bill Ward and Greg Swift.

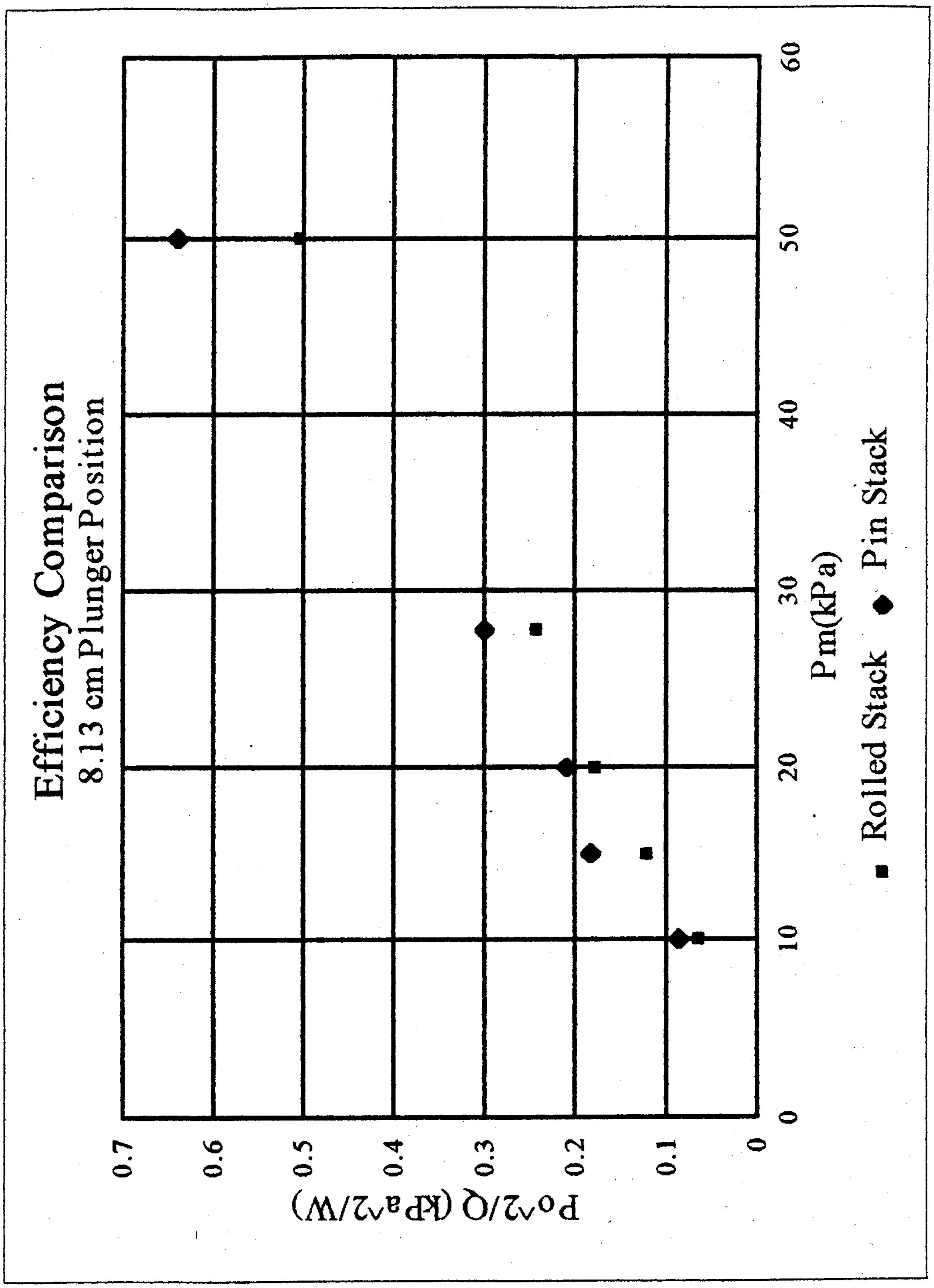
A rough measure of the efficiency improvement for the pin stack vs. the conventional stack can be made in terms of measured quantities by comparing the square of the acoustic amplitude divided by the heater power needed to keep the warm end of the prime mover near room temperature. In the second figure, this ratio can be seen to be about 25% better for the pin stack than for the conventional stack.

One surprise was how sinusoidal the acoustic waveforms are at these very high sound pressure levels, about 178 dB re 20 micro Pa. In figure 3, a typical waveform is shown at 89 kPa mean pressure and 46 kPa peak to peak pressure.



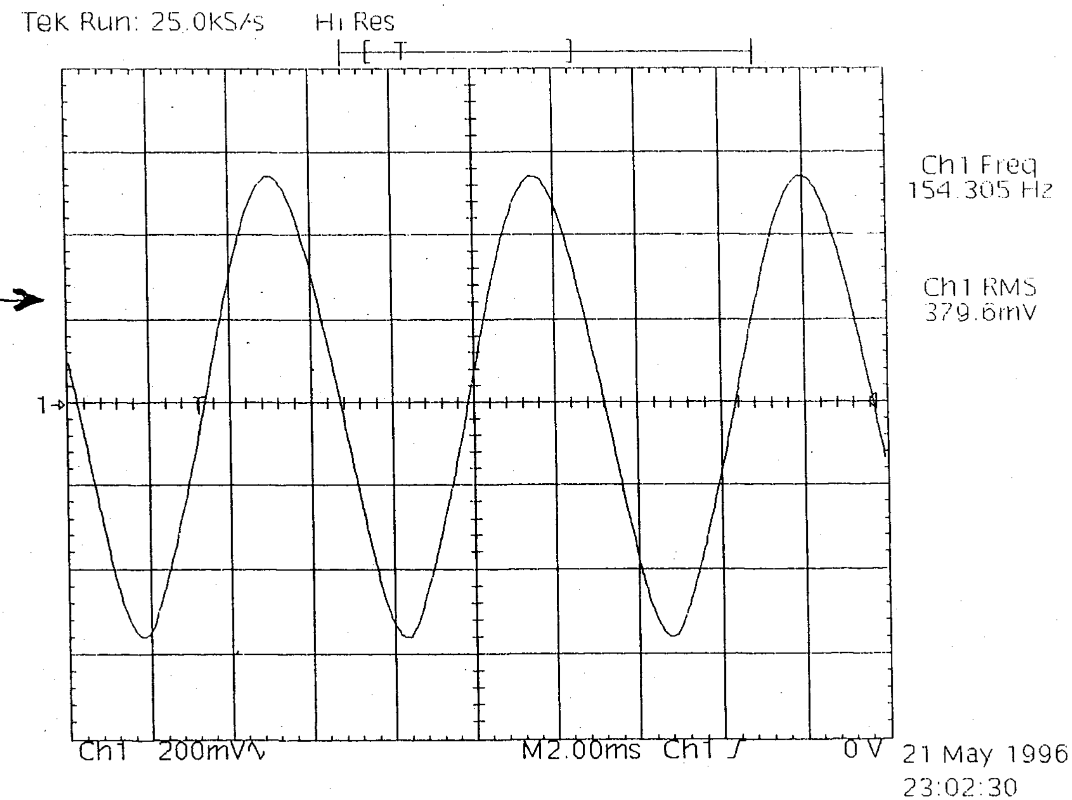
Stack Comparison, 8.13 cm plunger position
Pin Stack, Data
Pin Stack, DeltaE
Rolled Stack, Data
Rolled Stack, DeltaE
normalized acoustic pressure Po/Pm (% rms)
mean pressure Pm (Pa)
0
5
10
15
20
25
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

Figure 1



Efficiency Comparison
8.13 cm Plunger Position
Po^2/Q (kPa^2/W)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
Pm(kPa)
Rolled Stack
Pin Stack

Figure 2



1 ATM

VACUUM

Figure 3

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i. Number of contributed presentations at workshops or professional society meetings:	0
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P^3H Report Continued
01 June 95 through 31 May 96

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